FIRST SET OF LABORATORY VENUS ANALOG SPECTRA FOR ALL ATMOSPHERIC WINDOWS. J. Helbert[1], A. Maturilli[1], M. D. Dyar[2,3], S. Ferrari[4,1], N. Müller[5], S. Smrekar[5], [1]Institute for Planetary Research, DLR, Rutherfordstrasse 2, 12489 Berlin, Germany (joern.helbert@dlr.de), [2] Planetary Science Institute, 1700 East Fort Lowell, Tucson, AZ 85719, [3] Dept. of Astronomy, Mount Holyoke College, South Hadley, MA 01075, [4]Dept. of Earth and Environmental Sciences, University of Pavia, Via Ferrata 1 - 27100 Pavia, Italy, [5]Jet Propulsion Laboratory, California Institute of Technology, 4800 Oak Grove Dr., Pasadena CA, 91109.

Introduction: Interpretation of VNIR spectroscopy data from orbiters is known to require spectral libraries acquired under conditions matching those on the surfaces being studied. This is particularly true for Venus, which has extreme conditions on the surface: 460°C and 93 bars and a dense, CO_2-rich atmosphere. The permanent cloud cover of Venus prohibits observation of the surface with traditional imaging techniques over most of the visible spectral range. Fortunately, Venus' CO_2 atmosphere is transparent in small spectral windows near 1 μm. Ground observers have successfully used these, during the flyby of the Galileo mission at Jupiter, and most recently by the VMC and VIRTIS instruments on the ESA VenusExpress spacecraft. Observations have revealed compositional variations correlated with geological features [1-6].

In particular, the spectral region near 1 μm fortuitously permits acquisition of several channels of information where most Fe and transition metals in minerals have absorption bands, making interpretations about the redox state and transition metal contents of the surface possible [7]. Such analyses rely on a solid foundation of 1aboratory data acquired at high T only. As explained in [8], it is not necessary to mimic the surface pressure in such databases because the effects of the increased P on spectra are comparatively benign compared to measurements of mantle pressures with only slight pressure effects are observed in olivine and pyroxene [9,10]. Thus the primary spectral changes will result from T.

Accordingly, we describe here the start of a spectral database for Venus analog materials. For the first time, the community has to access to spectra obtained in emission, covering the spectral range from 0.7 to 1.2 μm (and beyond) and obtained at typical Venus surface temperatures of 460°C.

The Planetary Emissivity Laboratory (PEL): This project builds on several years of development at the Planetary Spectroscopy Laboratory (PSL) at DLR [11-13]. PSL successfully acquired funding from the European Union as part of the EuroPlanet consortium to extend the spectral coverage for high temperature measurements down to 0.7 μm.

PSL operates two Bruker Vertex 80V spectrometers, one installed in 2006 and recently upgraded and one acquired in 2015. The laboratory is located in a temperature-controlled room at the Institute for Planetary Research in Berlin. Both spectrometer are located on an optical table equipped with external chambers for emissivity measurements (**Figure 1**). The recently upgraded Vertex 80V is optimized for the near to far-infrared spectral range.

The unique feature of the PSL is a high-temperature chamber attached to the upgraded Vertex 80V that allows heating of samples to temperatures up to 1000K under vacuum conditions (medium vacuum - 10-100Pa) [14]. Samples are placed in steel cups equipped with type K thermopiles as temperature sensors. A copper induction coil installed in the chamber is connected to a Linntherm 1.5kW induction system to permit contactless heating of the ferromagnetic sample cups by induction. Spectral coverage is achieved with a combination of a liquid nitrogen-cooled MCT detector and KBr beamsplitter for the spectral range up to 16 μm and a DTGS detector with a multilayer beamsplitter for the remaining spectral range.

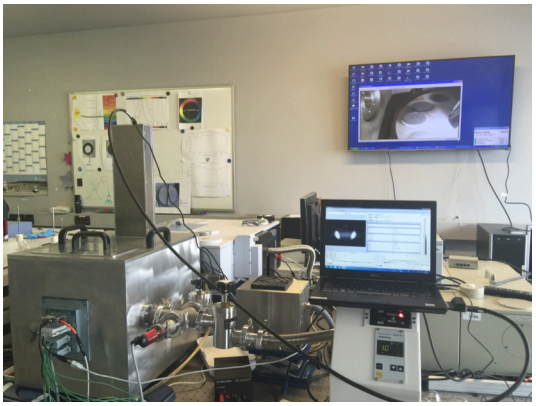

Figure 1. New setup at the Planetary Spectroscopy Laboratory (PSL) – including Venus Emissivity Mapper (VEM) prototytpe on the auxiliary port of the chamber [15].

The EU-financed upgrades accomplished in 2015-2016 include the new InGaAs detector with matching beamsplitter, an upgrade of the spectrometer electronics and an optimization of the optical layout in the chamber.

Laboratory experiments: Measuring emissivity at 1 μm at Venus analog temperatures is already very challenging for many reasons. As an example the emissivity of stainless steel increases strongly towards shorter wavelength at high temperatures. This results in a non-negligible contribution to total radiance from our sample cups. At the same time, many natural materials have a high transparency at 1 μm. To address this issue we have developed a ceramic enclosure (**Figure 2**) for

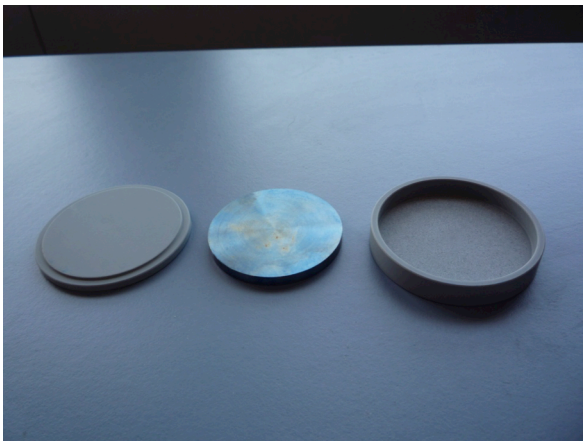

Figure 2. Newly developed ceramic enclosure for stainless steel sample holder.

the stainless steel that suppresses the radiation from the sample cups.

After extensive testing, the new setup at PSL for Venus analog measurements has been demonstrated to perform following our requirements. It is stable and produces reproducibility results. Therefore, we froze the design at the end of 2016 as our standard set-up for emissivity measurements of Venus-analogue samples in the visible spectral range.

Venus analog database: As a starting point for the database we obtained measurements of eight samples covering a range from felsic to mafic samples (**Figure 3**). This first set already shows that despite the limited number of available spectral channels, we will be able to map surface mineralogy from orbit with instruments like the Venus Emissivity Mapper [7, 15] (**Figure 4**).

Conclusions: Work in progress at the Planetary Emissivity Laboratory is laying the groundwork for collection of a spectral library for rocks and minerals under Venus conditions. Once acquired, these data will be key in understanding and modeling differences in emissivity between ambient and Venus conditions, potentially enabling calibration transfer between datasets.

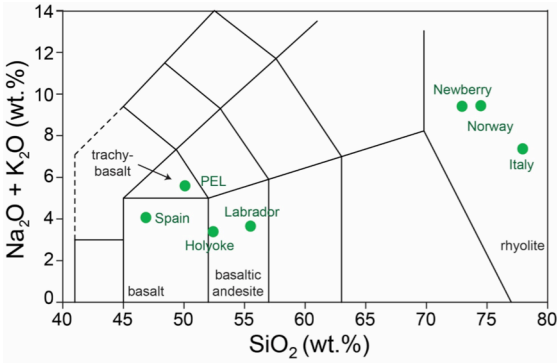

Figure 3. Compositions of seven of the initial samples in the database plotted on a total alkali versus silica diagram. An eighth sample is hematite-bearing and is not shown.

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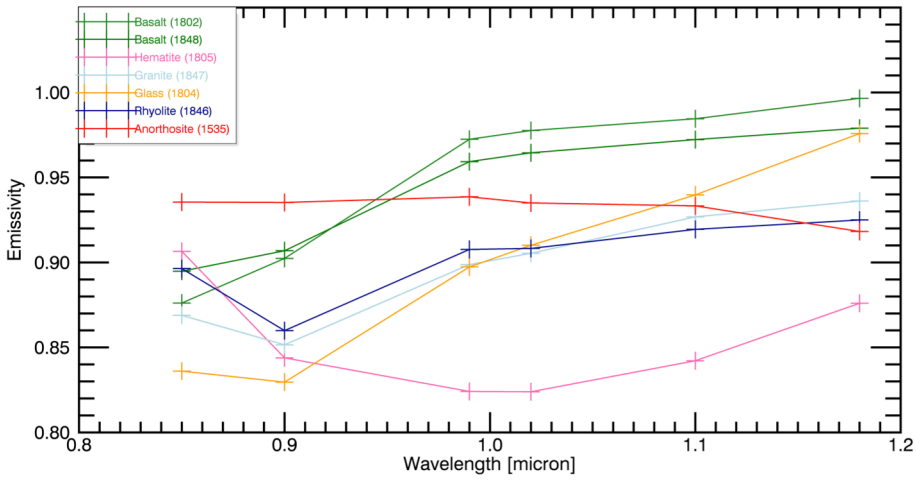

Figure 4. Spectra of Venus analog sample (PSL_ID in brackets) at all known atmospheric surface windows of Venus. Samples represent a suite of crustal differentiation and thus different Fe and Si concentrations. Hematite is a predicted surface weathering product of basalt. Additional spectral analysis techniques allow for robust identification of subtle spectral differences.